THE LATE PLEISTOCENE AND HOLOCENE HISTORY OF THE MIDLANDS OF TASMANIA, AUSTRALIA: POLLEN EVIDENCE FROM LAKE TIBERIAS

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ABSTRACT: During the late Pleistocene, markedly cold and dry climates in the Tasmanian central Midlands limited vegetation to sparse, treeless grasslands or possibly a chenopod steppe. Increases in temperature and effective precipitation between *c.* 11,000–9,000 B.P. resulted in the replacement of much of this vegetation with *Eucalyptus*-dominated formations. The ensuing vegetation, probably a mosaic of dry sclerophyll forest, woodland and grassland, has remained characteristic of the region up to the present.

Changes in the understory flora of *Eucalyptus* forests believed to be some distance from Lake Tiberias imply climates in the early to mid-Holocene slightly wetter than at present. This phase was followed by a reversion towards drier conditions leading to the modern subhumid climate. The pollen evidence is against previous concepts of mid-Holocene aridity in eastern Tasmania.

INTRODUCTION: THE REGIONAL SETTING

The Midlands of Tasmania comprise the long-settled belt of plains along the line of the Midlands Highway between Bridgewater and Perth (Fig. 1). Westwards, the Midlands are bounded by the scarp of the Central Plateau; to the east the region merges into the Eastern Tiers, low, much dissected plateaus inland of the east coast (see Map 5 in Davies 1965).

In cross-section (Fig. 2), the Midlands present a stepped appearance, interpreted as a sequence of relict erosion surfaces developed across Permian and Triassic sediments extensively penetrated by Jurassic dolerites (Davies 1959, 1967). A major erosion surface between 90 — 275 m above sea level is represented by the plains north of Tunbridge (the only extensive inland plains in Tasmania) and those around Kempton to the south. Lake Tiberias (42°22'S, 147°22'E, 442 m) occurs on the next higher erosion surface, the central Midlands. Dolerite-capped residuals of a yet higher surface (represented by the plains around Interlaken on the Central Plateau) are common on the central Midlands.

Aeolian sand sheets and lunette dunes of probable late last glacial age (Sigleo & Colhoun 1975) are widespread in the Midlands. Pleistocene solifluction deposits mantle the slopes of ridges down to 400 m: the high plateaus of Ben Lomond and the Central Plateau supported small icecaps (Derbyshire *et al.* 1965, Davies 1967).

Due to the pronounced west-east gradient in precipitation across Tasmania, the Midlands lie wholly within the rainshadow zone of the Central Plateau. In contrast to humid and perhumid climates over much of the island, the Midlands are subhumid (Gentilli 1972). Annual precipitation totals are everywhere less than 750 mm and do not significantly vary with elevation (see Nicholls & Aves 1961). Much of the precipitation is derived from infrequent incursions of moist air masses from the Tasman Sea, giving the Midlands one of the least reliable rainfalls in Tasmania (Scott 1956, Langford 1965). Variation in the strength of the prevailing westerly air stream is significant: the Midlands are driest when the westerlies are strongest (July — September) or, alternatively, absent (January — March, when evapo-transpiration losses exceed rainfall gains) (Bur. Met. 1975). Snow falls are rare.

Thermal regimes in the Midlands show a slight continental effect. Despite a mild annual mean temperature of 10°C at Oatlands (432 m), extremes recorded here (Max. 40°C, Min. −12.8°C) are greater than those at Miena (1,013 m) on the

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FIG. 1 — Location of Lake Tiberias.

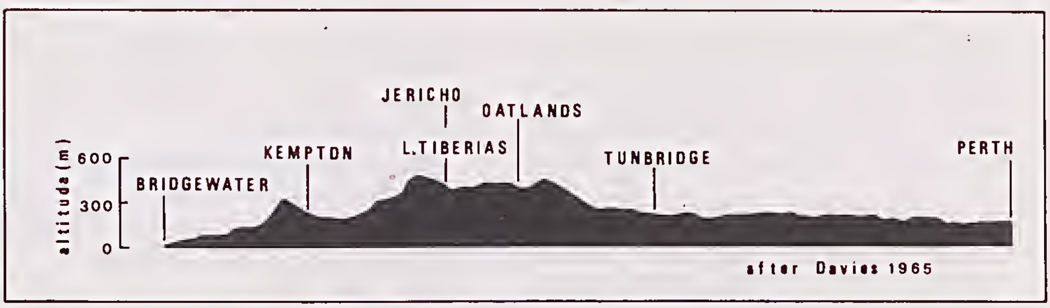

FIG. 2 — Profile along the Midlands Highway.

Central Plateau and there is no frost-free month (Foley 1945, Bur. Met. 1956).

The presence of saline lakes (Nye 1921, Buckney & Tyler 1972), free carbonates in sub-surface soil horizons (Cowie 1959, Leamy 1961) and open vegetation types (Jackson 1965, 1973) in the Midlands reflects the low effective rainfall.

The characteristics of soils developed are essentially correlated with the lithology of the parent material:

Triassic Sandstones, by far the most common sedimentary rock in the central Midlands, carry stony and infertile podzolic soils, podzols or shallow brown earths. Soils on siliceous strata are better-draining but less fertile than those on feldspathic and micaceous strata.

Permian Mudstones carry very infertile and shallow podzolic soils. These are liable to both rapid desiccation and waterlogging.

Dolerite, usually outcropping on ridge slopes and tops, carries podzolic soils of shallow, stony silt loams over plastic clay horizons. At low elevations, brown earths have developed. All dolerite soils are more fertile than those on sedimentary strata but are prone to waterlogging and rapid desiccation. Heavy textured black earths have developed on the more recent alluvium. Windblown sediments carry brown earths.

In contrast to the forested plateaus on either side, vegetation in the Midlands is characteristically savannah woodland on the interfluve ridge niche extending into tussock grassland in the broad shallow valley niche. Few, if any, plant communities have escaped firing or grazing pressures associated with Aboriginal and European occupation of the region. The former may extend back some 18,000 years (Bowdler 1974, Sigleo & Colhoun 1975). Although 'fire-stick farming' (Jones 1969) has probably maintained in the long-term the extensive Midlands grasslands, it is unlikely that present-day climates would support a vegetation type more closed in structure or mesic than *Eucalyptus* dry sclerophyll and woodland in the Midlands.

Organic lake deposits occurring in the Midlands are rarely more than 1 metre-deep black clays, impenetrable to hand-coring techniques. The presence of sedge peats 3 metres deep in Lake Tiberias therefore is an exceptional opportunity to explore the more recent past vegetation and climate of the central Midlands by pollen analysis.

THE STUDY SITE

Lake Tiberias (Pl. 28) occupies a shallow valley in Triassic sandstones at the head of the Jordan River, 10 km south of Oatlands. To the east, the next lower erosion surface, represented by the 180 m deep valley of the Coal River, comes within 0.8 km of the Lake; 100–250 m high dolerite ridges occur around the lake catchment area.

The lake basin is roughly triangular, *c.* 10 km^2 in area within a catchment area of *c.* 21 km^2. Lunette dunes occur along the southeastern shore, suggesting seasonal desiccation and deflation of the lake basin during the Pleistocene (see Bowler 1973). Minor streams, dry during summer, enter the lake at the northeast and southwest corners. Outflow is across a dolerite rock bar at the northwest end. Before the construction of a small, ineffectual weir across the outflow, the surface of the peat infill was probably close to the level at which water drained from the lake. At present the lake is hydrologically open only during winter. Consequently, the water is subsaline (R. T. Buckney, pers. comm.)

Meteorologic conditions at the lake would be similar to those at Oatlands (Table 1): overall cool, with a mean daily temperature above 10.5°C from October to March inclusive and an annual rainfall of 510 mm distributed (by Tasmanian standards) uniformly throughout the year.

Soils (Hubble 1946) and plant communities at Lake Tiberias follow the pattern common to the

TABLE 1

DISTRIBUTION OF RAINFALL AND EVAPORATION AT OATLANDS
(mm of rain)

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*Jul.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Yr.*
Precipitation, 1882-1964	42.9	41.1	40.1	50.0	56.0	54.1	43.2	43.9	41.9	57.7	48.8	57.4	567
Evaporation (est.)	130	100	75	50	40	25	25	25	40	50	75	100	710
No. rain days	9	9	10	13	15	16	17	17	14	15	14	12	161

After Bur. Met. (1966), J.E.S. Townrow (pers. comm.).

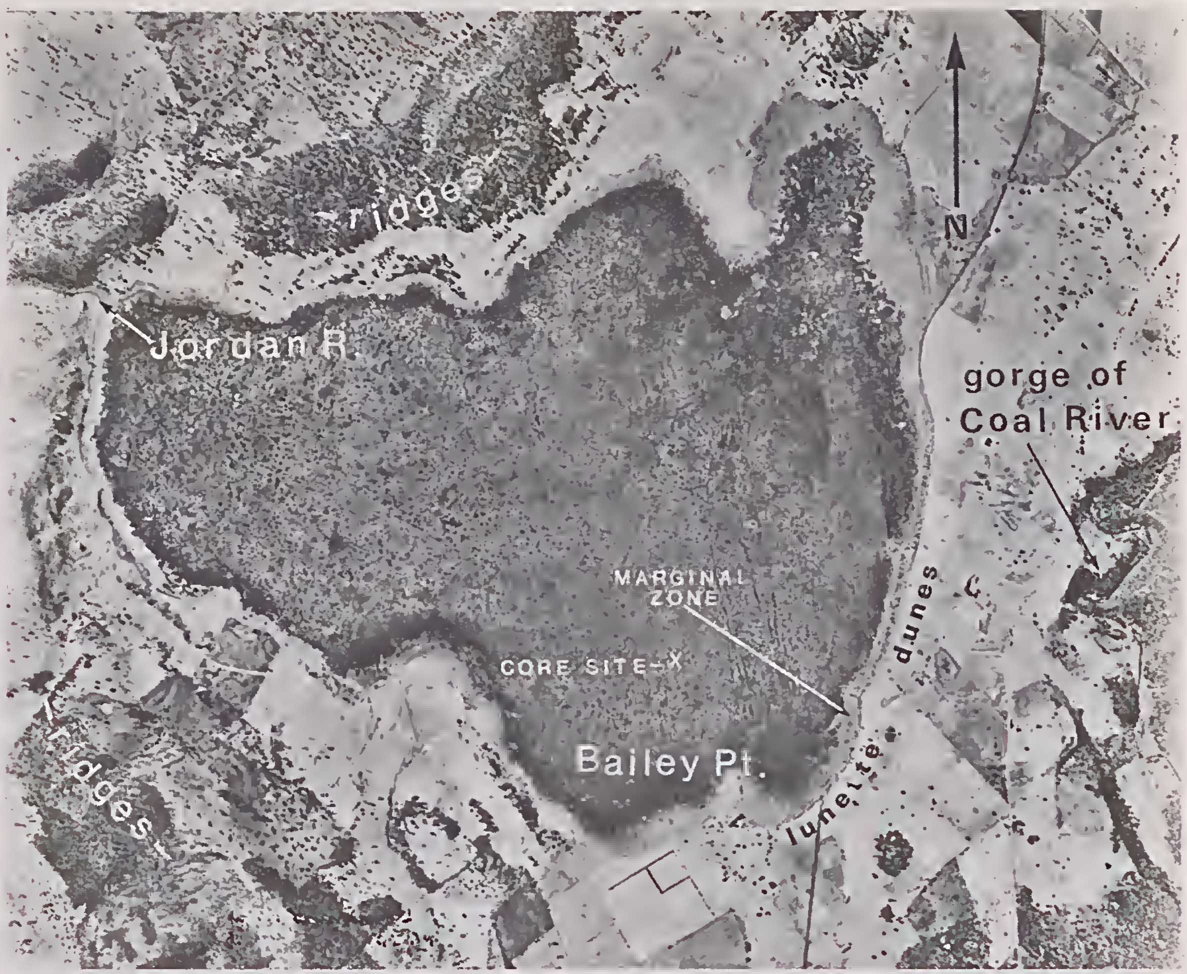

PLATE 28
Aerial photograph of Lake Tiberias.

Midlands. Consequently, dry sclerophyll forest occurs within 200 m, and isolated eucalypts adjacent to the lake. An estimated 20% of the catchment basin supports *Eucalyptus*-dominated formations (cf. Nye 1922). Plant names and authorities follow Curtis (1956-67) and Willis (1970).

Where uncleared (Pl. 28), the slopes of surrounding ridges support open-forest, low open-forest and woodland of *Eucalyptus ovata* — *E. pauciflora, E. viminalis* — *E. amygdalina* and *E. pauciflora* — *E. rubida* intermixed with small trees of *Exocarpos cupressiformis, Acacia dealbata, Banksia marginata, Dodonaea viscosa, Bursaria spinosa* and, on the driest sites, *Casuarina stricta*. Grasses are common as a ground cover. This contrasts with the predominantly xerophytic shrub understory (species of Epacridaceae, Proteaceae, Myrtaceae, Compositae, Papilionaceae and Mimosaceae) found in protected sites and in extensive *Eucalyptus* open-forests peripheral to the Midlands (see Map 7 in Jackson 1965). Isolated trees extend into the valley grasslands. Where unimproved, these grasslands are dominated by *Poa poiformis*. *Themeda australis* and *Lomandra longifolia* may be dominant on clayey soils. Grazing is the main form of land usage with small areas sown for fodder crops (Scott 1965). Besides introduced grasses, the exotic species *Ulex europeus, Taraxacum officinale, Plantago lanceolata* and *Trifolium* are common in the pastures.

Mesophytes are uniformly remote from Lake Tiberias. Wet sclerophyll species such as *Pomaderris apetala* and *Dicksonia antarctica* occur in damp gullies near the east coast and on the scarp of the Central Plateau to the north. The nearest stands of *Nothofagus cunninghamii* cool temperate rainforest and probably the light-demanding rainforest conifer *Phyllocladus aspleniifolius* occur 50 km to the south and southeast, on the Mt. Wellington Range and Prossers Sugar Loaf, but extensive rainforest (with *Phyllocladus* and *Dicksonia*) and alpine species such as *Nothofagus gunnii, Microstrobos* and *Podocarpus* are much more distant, on and west of Mt. Field and the northern rim of the Central Plateau.

With the exception of a marginal zone some 60 m wide (used as a water meadow), Lake Tiberias is covered by the one sedge species, *Lepidosperma longitudinale*. The structure of this sedgeland varies with the micro-relief of peat surface and the extent of disturbance by cattle: hummocky near the edge and sparse but continuous towards the centre. A coprophilous association of *Epilobium* and unidentified species of Solanaceae, Compositae and Gramineae occurs around those hummocks used by birds as nesting sites. Otherwise *Utricularia dichotoma* is usually the only other species to occur with the sedge dominant. In contrast, the marginal zone supports an exceedingly dense and diverse community of free-floating and rooted aquatics, including *Triglochin procerum, Myriophyllum propinquum, Villarsia exaltata, Scirpus fluitans* and species of *Potamogeton, Lemna* and Gramineae. Eutrophication effects are apparent and floristic dominance varies from year to year.

Water depths may exceed 1.5 m during winter. Water table levels tend to remain above the lake bed of organic muds in the marginal zone but elsewhere the lake dries out to form a mosaic of shallow pools and sedge 'islands' across the peat infill during summer.

Lake sediments were cored using a Hiller corer at a site *c.* 400 m north of Bailey Point (Pl. 28). These comprise 215 cm of well humified sedge peats overlying an unknown depth of lacustrine clays. An algal gyttja containing numerous shells of the freshwater gastropod *Potamopyrgus* (B. J. Smith pers. comm.) occurs at the junction. Depths measured from the surface of the rhizome mat are:

0 – 15 cm:	sedge bases, coarse fibrous peat
15 – 215 cm:	dark brown well humified to slightly fibrous peat
215 – 220 cm:	grey-green algal gyttja with gastropod shells
220 – 250 cm:	grey-brown clay
250 – 283 cm:	blue-grey clay

A gastropod shell horizon intercalated between the peat and clays was recorded at similar depths in two additional cores taken between this site and Bailey Point. Peats immediately overlying the gastropod horizon in another core taken by A. Goede (Geography Dept., University of Tasmania) prior to this study are dated at 9,550 ± 200 ^{14}C yr B.P. (GaK-2239), (Goede unpubl.). The apparently level nature of the off shore lake floor beneath the peat and similarities in stratigraphy make it likely that Goede's date is applicable to level *c.* 215 cm in this study.

PREPARATION OF THE POLLEN DIAGRAM

The core was sampled at 8 cm intervals in the field and the sealed samples returned to the laboratory. These were wet sieved, treated with cold hydrofluoric acid if clay-rich, and then with hydrolysis and acetolysis following the methods outlined by Faegri and Iversen (1964) and Franks (1965). Pollen and spores were counted at X 200 magnification and, when necessary, identifications checked at higher magnifications against a virtually complete pollen herbarium of the native Tasmanian flora prepared by M.K. Macphail. Whole mounts were counted to avoid under-coverslip sorting effects.

The pollen diagram (Fig. 3) is based on a pollen sum comprising the modern regional pollen rain in Tasmania, Gramineae, *Phyllocladus*, Chenopodiaceae-Amaranthaceae (listed as Chenopodiaceae in Fig. 3), *Casuarina, Pomaderris apetala*-type, *Dicksonia, Nothofagus cunninghamii, Eucalyptus* and Compositae in approximate order of decreasing representation, and other types known to be widely dispersed, *Dacrydium, Dodonaea, Bursaria, Acacia, Amperea* and *Pomaderris elliptica* (Macphail 1975, 1976). All pollen and spores from coastal, rainforest and highland species are long distance transported with respect to Lake Tiberias. *Nothofagus gunnii, Microstrobos* and *Podocarpus* are omitted from the pollen sum in order to bring the pollen sum into conformity with pollen sequences from montane Tasmania.

The pollen diagram has been subdivided by eye into local pollen zones defined by variations in the pollen curves of regional pollen producers.

Zone LT-1 (250 cm). The zone, comprising, one pollen spectrum (sample 32), is distinguished by high values for both Gramineae and Chenopodiaceae-Amaranthaceae, and an unidentified stephanoporate type, possibly aberrations of *Myriophyllum* or Chenopodiaceae-Amaranthaceae pollen. Otherwise *Phyllocladus* and *Eucalyptus* overwhelmingly dominate the dry land pollen component and *Myriophyllum* the hydrophyte pollen component.

Zone LT-2 (250-210 cm). Transitional zone with increasing pollen taxon diversity. The base is defined by a great increase in *Phyllocladus* and, to a lesser degree, *Eucalyptus* at the expense of Gramineae and Chenopodiaceae-Amaranthaceae. Thereafter, *Phyllocladus* values (and those of the stephanoporate type) decrease over the zone whilst *Eucalyptus* rises to make up 60% of the pollen sum. Equally diagnostic of the zone are maximum values for *Dicksonia*, Compositae, the herb *Oreomyrrhis* and fern spores. Patterns in the hydrophyte component are similar: *Myriophyllum* rises greatly in abundance at the base and remains very common throughout; *Cladium-Lepidosperma* is initially common but thereafter decreases whilst *Triglochin* increases across the zone.

Zone LT-3 (210-0 cm). Eucalyptus makes up 70-80% of the pollen sum. Values for rainforest taxa and Chenopodiaceae-Amaranthaceae are low to negligible throughout, with no discernible trends of any significance. A pollen type conforming to that of *Pomaderris apetala* but possibly including some variants of *Spyridium* rises abruptly in value to 16% at 184 cm then decreases in irregular fashion to 2-4% over the zone. Conversely, *Casuarina* and Gramineae increase to 10% of the pollen sum in the upper third of the zone. Fluctuations in the hydrophyte component are more marked. The zone is informally subdivided according to changes in the relative proportions of sedge and aquatic pollen types:

(i) High percentages of *Myriophyllum*, sporadically high values for *Triglochin, Cladium-Lepidosperma* and Restionaceae and increasing representation of the sedge pollen taxon *Heleocharis-Scirpus*.

(ii) Initially high and thereafter decreasing values of *Heleocharis-Lepidosperma* with negligible values of *Myriophyllum* and *Cladium-Lepidosperma*.

(iii) Low to moderate percentages of *Cladium-Lepidosperma* with negligible values of *Heleocharis-Scirpus, Myriophyllum* and *Triglochin*.

INTERPRETATION OF THE POLLEN DIAGRAM

Interpretation of the pollen diagram (Fig. 3) relies heavily on the present-day distribution of the source plants across Tasmania (see Appendix) but is supported by a study of the modern pollen rain across Tasmania (Macphail 1976). Negligible amounts of pollen from the marginal zone aquatics in the surface sample suggest that the sedge cover greatly restricts the movement of pollen within the lake basin. Hence the dispersal of dry land pollen types into off-shore areas is by atmospheric rather than by water transport processes. The hydrophite pollen component is unlikely to represent more than vegetation at the core site: sporadic occurrences of pollen and spores from severely under-represented species, including most sclerophyll understory shrubs (Macphail 1975) are of little significance.

Conversely, pollen from any regional pollen producer likely to have always been remote from Lake Tiberias serves as a measure of the abundance and or proximity of other strong pollen sources likely to grow closer to the lake. In this analysis, *Phyllocladus* is such an indicator. The conifer is now restricted to wetter-humid and perhumid situations and, pollen-wise, local stands can be identified by high values of *Pomaderris apetala, Dicksonia* or *Nothofagus cunninghamii.* Whilst there is evidence (Macphail 1976) that *Phyllocladus* formed a now non-extant association with *Eucalyptus* in the early postglacial under climates drier than at present, there is none to suggest *Phyllocladus* could tolerate subhumid conditions, however fertile or fire-free the site.

The pollen diagram illustrates concurrently (i) the development of a freshwater lake colonized by aquatic taxa, then sedges and (ii) the replacement of a sparse grassland association by open *Eucalyptus* formations.

LT-1: Sparse Grassland Associations

The appearance of *Myriophyllum* at 251 cm, above sediments virtually devoid of pollen and spores, suggests zone LT-1 reflects the flora of the Midlands at the end of a period in which Lake Tiberias was seasonally or perennially dry. High pollen values for *Phyllocladus* and *Eucalyptus* in this zone and the early part of LT-2 imply these assemblages (from clays sparse in dry land pollen) are the time stratigraphic equivalents of, and have the same sources as, assemblages recording the development of *Phyllocladus-Eucalyptus* formations on mountains in western and southern Tasmania between 11,000 — 10,000 ^{14}C yr B. P. (Macphail 1976) i.e., zones LT-1 and early LT-2 are late Pleistocene.

Values for other dry land pollen types agree with a distant point of origin for much of the pollen and spores in zone LT-1. *Casuarina* percentages are similar to values reflecting long distance transport elsewhere in Tasmania. Assuming the stephanoporate pollen type is not Chenopodiaceae or Amaranthaceae, values for Chenopodiaceae-Amaranthaceae are below that in a surface sample from within a chenopod community (Hope 1969) but approach values recored in pollen traps in western Tasmania during the island-wide absence

LAKE TIBERIAS. MIDLANDS, TASMANIA.

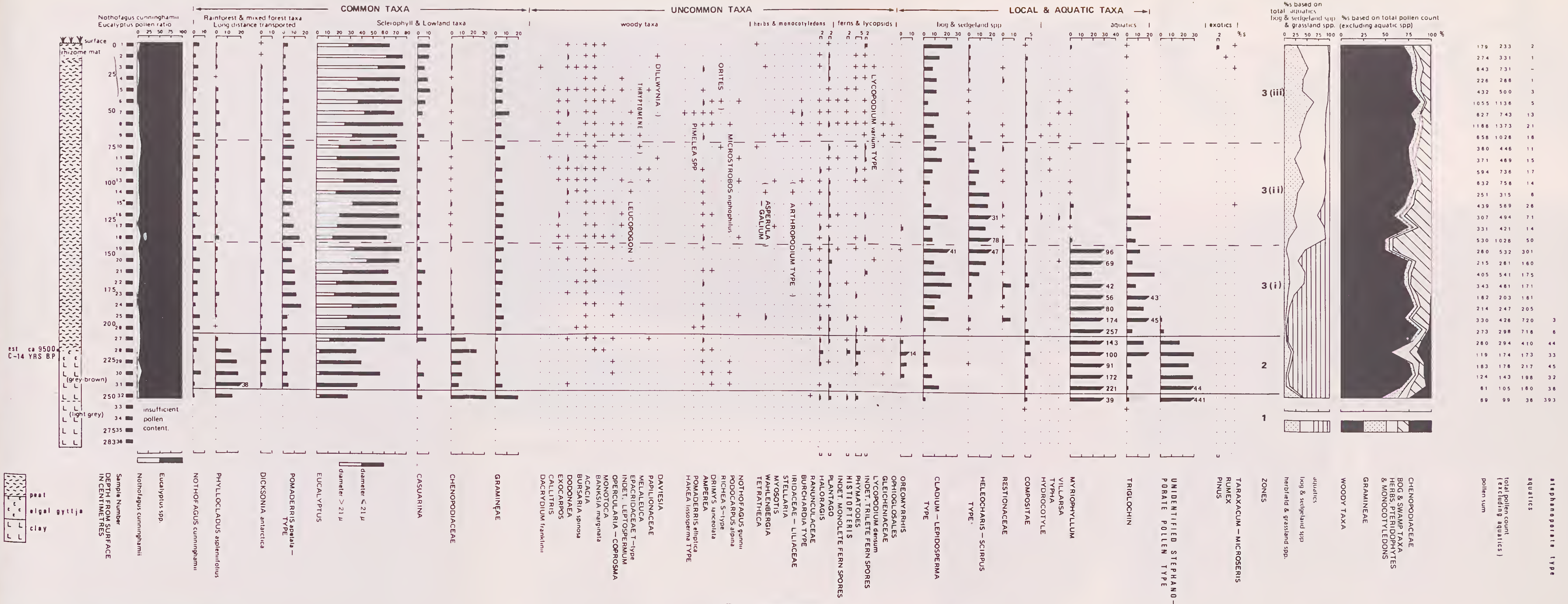

FIG. 3 — Pollen Diagram.
The frequencies of occurrence of all pollen and spores are shown as percentages of the total arboreal pollen plus Gramineae, and long distance transported pollen, of the appropriate sample. (%s less than 1 recorded as +).

of flowering in winter. Accordingly, at least part of the chenopod pollen count may have been derived from mainland communities (cf. Martin 1973). *Eucalyptus* values are accentuated by the pollen sum used and, in any case, are well below the surface sample value. Gramineae values are below those representing local grasslands but are also below values reflecting long distance transport during the late Pleistocene in Tasmania (Table 1 in Macphail 1975).

Therefore, late Pleistocene vegetation in the Central Midlands is likely to have been sparse, most probably very open grasslands lacking trees. Since vegetation on the erosion surface adjacent to but 180 m below Lake Tiberias probably contributed significant amounts of pollen to the local pollen rain, late Pleistocene vegetation on this surface may also have been sparse (cf. Sigleo & Colhoun 1975).

Pollen from *Oreomyrrhis* in zone LT-2 is evidence for markedly colder conditions in the Midlands before *c.* 9,500 ^{14}C yr B. P. (Appendix). Since Lake Tiberias was close to, if not above, the lower limits of late Pleistocene periglacial activity (Davies 1967, Chick & Colhoun 1972), an absence of trees on the higher Midlands in the late Pleistocene is not surprising, whatever the precipitation regime. The inferred sparsity of grasses is however less likely to result from low temperatures. A more probable cause is precipitation values rather lower than the present-day subhumid conditions.

Zone LT-1 therefore indicates that late Pleistocene climates in the Midlands were colder and drier than at present. These conditions are consistent with a late Pleistocene age for aeolian landforms in inland eastern Tasmania and support Flint's hypothesis of accentuated precipitation shadowing effects during glacial periods (Flint 1957 p.432). The modern relationship between dry conditions in eastern Tasmania and strength of the prevailing surface westerly airstream suggests glacial age aridity in Tasmania may well have been associated with increased vigour of the zonal circulation relative to the present (see also Derbyshire 1971, Wilson & Hendy 1971).

The possibility remains that zone LT-1 reflects a chenopod 'cold steppe' community in the Midlands, analogous to the Gramineae-Chenopodiaceae associations of (hot) semi-arid to arid regions of mainland Australia. Gramineae-Chenopodiaceae associations are now rare in inland Tasmania (Appendix in Macphail 1975) and the demise of such a chenopod steppe would be in accordance with the onset of more equable climates across Tasmania during the Holocene.

LT-2: Expansion of *Eucalyptus*

Trends in the pollen curves of wet forest species in zone LT-2 are consistent with, and the pollen and spores probably derived from *Nothofagus cunninghamii* rainforest and *Eucalyptus* wet sclerophyll replacing *Phyllocladus-Eucalyptus* communities on mountains to the west and south of Lake Tiberias between 10,500 — 9,500 ^{14}C yr B. P. (Macphail 1976). Chenopodiaceae-Amaranthaceae pollen values are in agreement with a distant point of origin for much of the dry land pollen and spores in the zone. Despite low Gramineae pollen values, vegetation in the higher Midlands probably remained sparse grasslands. Increasing values for *Eucalyptus* pollen in zone LT-2 are therefore likely to reflect an expansion of eucalypt formations at lower elevations in eastern Tasmania before 9,500 ^{14}C yr B. P.

Since *Eucalyptus* and rainforest trees were well established at elevations higher than but west and south of the central Midlands by 10,000 ^{14}C yr B. P., the difference in time of development (and floristics) of postglacial forests suggests progressive amelioration in climate along a gradient approximating to the modern west-east precipitation gradient. Accordingly, climates in the Midlands during zone LT-2 are likely to have been less severe than for zone LT-1 but still cold and dry relative to the present.

The presence of local *Myriophyllum* then *Triglochin* suggests lake levels remained constantly above the lake floor at the core site during zone LT-2. *Potamopyrgus* shells show that freshwater conditions were present by 9,500 ^{14}C yr B.P.

LT-3: Local Dry Sclerophyll Forest and Savannah Woodland

High values for *Eucalyptus* pollen throughout zone LT-3 (similar to the surface sample value) indicate eucalypts became common on the higher Midlands shortly after 9,500 ^{14}C yr B.P., probably as effective precipitation, and possibly temperatures, reached values close to those of the present-day. A marked rise in the proportion of *Eucalyptus* pollen with diameters greater than 21μ occurs across the zone LT-2/LT-3 boundary. This is consistent with an expansion of warmth-requiring eucalypts since now only those species characteristic of the upper subalpine zone — on dolerite, *Eucalyptus coccifera, E. subcrenulata* and *E. vernicosa* — have pollen always smaller than 21μ diameter. However, the change in pollen size classes also coincides with the initial phases of peat accumulation. Hence altered pollen extraction procedures (the treatment of clay but not peat samples with HF) might equally well be the explanation.

Other dry land pollen types maintain values across zone LT-3 that are similar to values in the surface sample, e.g. *Nothofagus cunninghamii, Dicksonia, Phyllocladus*, Chenopodiaceae-Amaranthaceae and, within broader limits, Gramineae. This suggests the central Midlands has supported a mosaic of *Poa* grassland with *Eucalyptus* dry sclerophyll forest and woodland since the early Holocene. As it is also probable that the Midlands supported Aboriginal populations during this period, the stability in vegetation may be as much due to a constant fire pressure as to climates remaining subhumid throughout. Minute carbonized particles were present in all peat samples but never in significant concentrations. However fluctuations in the *Eucalyptus* pollen curve, e.g. at the sub-zone 3i/3ii interface, may reflect the variable impact of local fires.

At present fire is a major influence in the Tasmanian environment (Jackson 1968). This emphasizes the need for caution when interpreting palaeo-ecologic evidence from long-inhabited regions. However, given the strong probability that man has been overwhelmingly responsible for past and present wildfires in Tasmania and that fire frequencies about centres of Aboriginal occupation were as high as the prevailing climate permitted (see Jackson 1968, Jones 1968, 1971), then the 'ecologic drift' in plant communities will again provide a relative measure of climatic trends even though meteorologic values are obscured in absolute terms.

One such indicator is the understory flora in *Eucalyptus* forests. Here, of the species which effectively disperse abundant pollen or spores, *Pomaderris apetala* and *Dicksonia* point to a moist forest environment and *Casuarina* and *Dodonaea* to a dry forest environment. Maximum values in zone LT-3 of the respective pollen and spore types suggest the substratum vegetation being represented was distant rather than local, possibly that of forests on the Central Plateau scarp and the Eastern Tiers.

On this basis, the irregularly high values for *Pomaderris apetala*-type pollen in sub-zone 3i and 3ii imply wet sclerophyll forest was then more abundant or located closer to Lake Tiberias within the pollen source area than at present. Assuming relatively constant rates of peat accumulation during zone LT-3, this in turn suggests that effective precipitation in the Midlands during the early to mid-Holocene was above modern values but still inadequate for a general expansion of *Dicksonia* within the same moist forest niche.

Low values of *Pomaderris apetala*-type pollen in subzone 3iii correspond to increasing percentages of *Casuarina, Dodonaea* and Gramineae pollen, suggesting that sclerophyll forests within the pollen source area have become increasingly dry and open-structured since the mid-Holocene. Since *Casuarina* is more fire-sensitive than *Eucalyptus*, an increase in fire frequency alone seems insufficient to account for the expansion of *Casuarina*. Accordingly it is suggested that the postulated wetter phase was followed by less equable conditions leading to the present-day subhumid climate in the Midlands. Less frequent incursions of moist air masses from the Tasman Sea or a shift in the orientation of the Central Plateau rainshadow effect could increase the water deficit period in the Midlands.

At the time of European settlement, Aboriginal population densities are calculated to have been amongst the highest known for 'hunter — gatherer' economies (Jones 1971), presumably due to expanding numbers during the Holocene. An alternative hypothesis, that the increasingly dry, open vegetation of the Midlands was due to an expansion in Aboriginal numbers, is considered less likely since montane rainforest in western and southern Tasmania (areas rather more remote from population centres) changed towards drier *Eucalyptus* dominated formations over approximately the same period (Macphail 1976).

The pollen data are inadequate to determine trends in temperature in zone LT-3.

Hydroseral developments at the core site in zone LT-3 are more clearly defined but less easily interpreted than the dry land vegetation. The stratigraphy demonstrates that this *in situ* vegetation has been a sedgeland since the early Holocene. For much of this period, the sedge dominant has probably been *Lepidosperma*. The temporary rise to dominance of the sedge community corresponding to the *Heleocharis-Scirpus* pollen type in the mid-Holocene was followed by the re-establishment of the '*Lepidosperma*' association. This reversion is likely to reflect changing water levels rather than a natural seral progression, hence a change in effective precipitation.

The marked decline in pollen from the open water aquatics, *Myriophyllum* and *Triglochin*, across the sub-zone 3i/3ii boundary suggests that (locally) sustained high water levels were replaced by alternating drying out and flooding of the peat surface at some time during the mid-Holocene, presumably as the rhizome mat reached the mean summer level of the water table. Any trend towards lower effective precipitation would compound this change in local hydrology. However it is clear from the pollen record that desiccation of the lake has not been sufficiently prolonged to allow the establishment of woody shrubs at the core site.

CONCLUSIONS

Pollen assemblages preserved in Lake Tiberias do not support the drier mid-Holocene episode postulated for eastern Tasmania between *c.* 7,000 — 3,000 B.P. by Davies (1974). Rather the model proposed here for late Pleistocene and Holocene climates in the Midlands is consistent with those established for montane regions in the southern half of Tasmania (Macphail 1976): markedly colder, drier conditions in the late Pleistocene, a rapid amelioration in temperature and precipitation between *c.* 11,000 — 9,000 B.P. leading to an early to mid-Holocene 'optimum' in which climates were wetter (and then possibly warmer) than at present and subsequently, a reversion towards less equable conditions leading to the modern climate. Recent phases of valley alluviation and aeolian deposition in southeastern Tasmania may well reflect the geomorphic impact of Aboriginal fires during short-term periods of severe climate (see also Goede 1965).

Revision and extension of this model of climatic change will require much additional pollen data well supported by radiocarbon dates. Cleveland Lagoon 15 km north of Campbell Town may prove suitable for palaeo-ecologic research. Pollen analysis of the Pleistocene clays infilling Lake Tiberias and many other of the Midlands 'lagoons' may extend the history of the region into earlier Quaternary times.

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APPENDIX

Source Plants for Pollen in Tasmania

Climates in Tasmania range from cool, perhumid on the west coast to warm, subhumid on the east coast. Plant communities are broadly zoned along this precipitation gradient and upslope on mountains with (increasing) precipitation and (decreasing) temperature. The climatic timberline varies in altitude from 750-915 m in the southwest and west to 1,220 m in the northeast and east. Subalpine climates extend some 300 m below the timberline.

The wide range of microclimates created by the island-wide mountainous terrain blurs boundaries between plant formations. Much of the vegetation is fire-disturbed. As a result, many sclerophyll species characteristic of drier eastern climates are widespread in perhumid environments in the far south, southwest, west and northwest, regions climatically capable of supporting *Nothofagus cunninghamii* cool temperate rainforest from sea level to the timberline: species characteristic of wet sclerophyll forest are common within disturbed rainforest.

Soils in eastern Tasmania are developed on relatively fertile Mesozoic sediments and dolerite; those in western Tasmania are developed on highly infertile Precambrian metamorphic rocks. Soil impoverishment associated with repeated fires helps maintain open-structured sclerophyll and sedge communities in the closed-forest niche.

Pollen Taxon	Family	Plant Habit	Known Ecology and Distribution
Acacia	Mimosaceae	Shrubs & trees	Mainly in coastal heath, drier sclerophyll forests and (*A. melanoxylon*, *A. verticillata*) along wet gullies and river banks. *A.dealbata* is common in wet forests disturbed by fire.
Amperea	Euphorbiaceae	Low shrubs	In heath and (western Tasmania) on poor soils.
Arthropodium	Liliaceae	Herbs	Locally common in open areas in eastern Tasmania.
Asperula-Galium	Rubiaceae	Herbs	Mainly in drier open situations up to 1,220 m.
Banksia marginata	Proteaceae	Shrubs & under-canopy trees	Widespread in coastal communities, drier sclerophyll forest and subalpine woodland up to 1,067 m.
Beyeria	Euphorbiaceae	Shrubs	Common on gully sides in eastern Tasmania.
Burchardia	Liliaceae	Herbs	Open situations in northeast.
Bursaria spinosa	Pittosporaceae	Small trees	Common in open woodlands and dry sclerophyll forest in eastern Tasmania.
Callitris	Cupressaceae	Small trees	Local on east coast and near Launceston.
Casuarina	Casuarinaceae	Shrubs & under-canopy trees	Widespread in coastal communities and on very dry hillsides inland in eastern Tasmania. *C. monilifera* is abundant on freely-draining sites in heathland up to *c.* 600 m in western Tasmania.
Chenopodiaceae-Amaranthaceae	Chenopodiaceae & Amaranthaceae	Herbs & shrubs	Rare inland of coast. Not in forests, heath or at higher elevations than the Midlands.
Cladium-Lepidosperma	Cyperaceae	Herbs	Swamps and wetlands at lower elevations.

APPENDIX (Continued)

POLLEN TAXON	FAMILY	PLANT HABIT	KNOWN ECOLOGY AND DISTRIBUTION
Compositae	Compositae (Asteraceae)	Herbs, shrubs & subcanopy trees	Widespread and locally abundant in all communities except undisturbed rainforest.
Dacrydium franklinii	Podocarpaceae	Emergent trees	Local in riparian rainforest and around lakes up to 750 m in far south, southwest, west and northwest.
Daviesia	Papilionaceae	Shrubs	Heaths and open situations in eastern Tasmania.
Dicksonia antarctica	Dicksoniaceae	(Tree fern)	Wet gullies and wetter sclerophyll forests up to *c*. 600m in eastern Tasmania. Rare on infertile soils (much of western Tasmania). Not in undisturbed rainforest.
Dillwynia	Papilionaceae	Low shrubs	Heath and grasslands in eastern Tasmania.
Drimys lanceolata	Winteraceae	Shrubs & small trees	Widespread in wetter forests (not undisturbed rainforest), subalpine and alpine heaths.
Epacridaceae (T-type)	Epacridaceae	Shrubs & small trees	Widespread and abundant in open communities from sea level to mountain summits (1,520 m).
Eucalyptus	Myrtaceae	Canopy trees	Dominants of sclerophyll forests and subalpine woodlands. Common as emergent above regenerating rainforest. Subalpine species may occur as isolated shrubs above the timberline in western Tasmania.
Exocarpos	Santalaceae	Shrubs & parasitic trees	Open-woodland and dry sclerophyll forest. *E. humifusus* is common in subalpine woodland and alpine heath.
Gramineae	Gramineae (Poaceae)	1. Aquatic herbs 2. Dry land herbs	Widespread but occasional in very shallow lakes. Dominant on Midlands plains, cleared lands elsewhere and frost-prone plains on the eastern Central Plateau. Rare within forests and alpine communities.
Gleichenia	Gleicheniaceae	(Fern)	Mainly subalpine and alpine bog communities.
Hakea lissosperma	Proteaceae	Tall shrubs	Subalpine woodlands, reaching sea level in southwest.
Haloragis	Haloragaceae	Herbs	Common in open, usually damp, situations from sea level to mountain summits.
Heleocharis-Scirpus	Cyperaceae	Herbs	Freshwater lakes including high altitude tarns.
Histiopteris	Dennstaedtiaceae	(Fern)	Widespread in wet shady places and burnt wet forests.
Hydrocotyle	Umbelliferae	Herbs	Stream banks and wet places below subalpine zone.